FY2009 Learning Technologies Grants Proposal

(COVER PAGE)

Project Information

Using Technology in the Field and Classroom for the Analysis of Seismic Waves

Project Title

Robert B. Hawman, Associate Professor _____

Project Director

Geology

Requesting Department

$12,487.35	$13,100.00
Amount Requested Year 1	Amount Requested Year 2

Project Director's Signature

Proposal Endorsement Signatures

Department Head

Dean

Proposal Abstract (100-word maximum)

The goal of the project is to train students in state-of-the-art methods for analyzing seismic waves. Students will gain experience in the design and execution of field experiments and in the inversion of data for models of subsurface structure. The work will be appropriate for students taking courses in geophysics, environmental geology, hydrology, forestry, soil science, and archeology. The project is consistent with University goals to involve more undergraduate students in research. The new facilities will encourage growth in the number and scope of interdisciplinary projects through the sharing of equipment and faculty expertise across several departments and schools.

Section I. Project Description

A. Nature of the Innovation

Seismic waves are powerful tools for investigating the structure and composition of Earth's interior. In the early 20th century, analysis of seismic waves generated by large earthquakes established the existence of Earth's molten core. More recently, seismic waves have been used to image descending slabs and other components of mantle convection systems associated with the motion of tectonic plates. At a smaller scale, seismic soundings using waves generated by small explosions and various impact devices are the principal tools used by the petroleum industry in the search for oil and gas. Similar techniques are now being applied to the study of soil horizons, the water table, archeological sites, and other important features in the shallow subsurface.

The goal of the work proposed here is to train students in two state-of-the-art methods for analyzing seismic waves. The first method (tomographic inversion of P waves) uses an approach similar to medical tomography to map variations in travel times of refracted P waves (compressional waves) into detailed 2D and 3D subsurface models of P-wave velocity and density. The second method (inversion of seismic surface waves such as Rayleigh waves) uses measurements of dispersion (dependence of velocity on frequency) to derive 2D and 3D models of S-wave (shear-wave) velocity. The velocities of both types of wave are sensitive to variations in chemical composition and fluid content and thus yield important constraints on the nature of materials at depth. Both methods can be applied at all scales, from mapping of convection systems in Earth's mantle and hydrocarbon exploration to the search for groundwater in the shallow subsurface.

The proposal calls for the purchase of a set of 4.5-Hz "geophones" (compact seismometers) that will allow students to collect their own data in the field. Students will gain experience in the design and execution of field experiments, in the processing of the raw wavefield data (e.g., in the identification of P waves and in the measurement of surface-wave dispersion), and in the inversion of that data for detailed models of shallow structure. The work will be appropriate for students taking courses in geophysics, environmental geology, hydrology, forestry, soil science, and archeology. The 4.5-Hz natural frequency of the geophones will yield broadband waveforms for both P waves and Rayleigh waves that will be suitable for imaging structures to depths of 100 meters. This will be deep enough to image soil horizons, the water table, karst features in limestone terranes (e.g., in northwest Georgia), and the often complex transition from soil to heavily weathered bedrock ("saprolite") to unweathered bedrock that is characteristic of the Georgia Piedmont.

Field experiments will involve the deployment of geophones in linear arrays. Seismic waves will be generated by a variety of impact sources (including a simple sledgehammer). During a typical experiment, which may last from one afternoon to several days, the geophone arrays and source stations are gradually moved along a series of profiles. The resulting redundancy in seismic raypath coverage (each geophone recording energy from sources at a large number of positions) is exploited by the inversion routines to generate detailed models of the subsurface. Initial target sites will include watersheds within the USDA J. Phil Campbell, Sr. Natural Resource Conservation Center in Watkinsville, sinkholes and other karst features in the limestone terranes of NW Georgia, and archeological sites throughout the state.

The data will be analyzed with two commercial software packages, one for tomographic analysis of P waves and the other for dispersion analysis of Rayleigh waves. The software packages can also be applied to "synthetic" waveform data generated for arbitrary input models. The latter approach can be used for simulating the analysis of earthquake-generated waves for larger-scale Earth structure and also for detailed studies of the mathematics of the inversion process. These types of analyses will be investigated in graduate-level courses in geophysics.

B. Need/Rationale

The proposal calls for the purchase of new hardware and software that is not currently available at the university. As noted in Part **A**, field experiments, lab exercises, and classroom demonstrations will introduce students to the principles of seismic imaging and to a broad array of applications (see also Part **D** below). The involvement of students from a number of different departments will encourage new interdisciplinary research projects (see Parts **C** and **D**).

C. Relevance of the Project to Unit and University Priorities

The project will help the Department of Geology and University achieve important educational goals in several key areas:

1. The proposed work will contribute to efforts by the Department of Geology to provide students with more field-based training in the geosciences.
2. The project will enhance the Geology Department's efforts to broaden its course offerings in geophysics, environmental geology, hydrology, and theoretical and applied seismology.
3. The project will also enhance the Geology Department's efforts to broaden and strengthen student training in quantitative methods of data analysis.
4. The project is consistent with University goals to involve more undergraduate students in research. The new hardware and software will provide geology undergraduates with a greater range of options for senior thesis projects and thus will help to accommodate the growing number of students who participate in Geology's optional senior thesis program.
5. The new facilities will encourage growth in the number and scope of interdisciplinary projects through the sharing of equipment and faculty expertise across several departments and schools of the University. Examples of possible projects include combined surface wave / tomography / electrical resistivity surveys with faculty in Crop & Soil Sciences and Forestry (using Forestry's existing resistivity equipment and software for inversion of resistivity data), and combined surface wave / tomography / electromagnetic surveys with faculty in Anthropology.

D. Specific Courses or Student Groups Benefiting from the Project/Number of Students Served

Extensive field and laboratory projects using the new hardware and software will be incorporated immediately into senior/graduate level courses in geophysics (GEOL 4600/6600 and 4620/6620). More advanced work with the software will be pursued in graduate courses in seismology (GEOL 8600) and data processing (GEOL 8030). Projects and demonstrations of

shorter duration will be added to a Geology core class (GEOL 3020), courses in hydrology (GEOL 4220/6220 and 8700), geoarchaeology (ANTH/GEOL 4700), physical geology (GEOL 1250), Honors Science (HONS 2080H), and to the optional field-trip program for students in GEOL 1121.

As noted in Section **C**, the project has potential benefits for undergraduate and graduate students in Forestry and Crop and Soil Sciences as well. Initially the work for those courses will be in the form of guest lectures and demonstrations of equipment and software. These will build on (and go well beyond) the material in existing joint-enrollment courses between Geology and those departments. It is hoped that the demonstrations will encourage students to use the new equipment and software in their own research.

A partial list of courses that will benefit from the program:

Course #	Course Title	Approximate enrollment/year
GEOL 1121	Earth Processes & Environments	1000 (about 40 would participate)
GEOL 1250	Physical Geology	40
GEOL 3020	Surface & Near-Surface Processes	15
GEOL 4220/6220	Hydrogeology	50
GEOL 4600/6600	Solid Earth Geophysics	7-10
GEOL 4620/6620	Exploration Geophysics	10-17
ANTH/GEOL 4700/6700	Archaeogeology	35
GEOL 8030	Advanced Topics in Geophysics	5
GEOL 8600	Advanced Topics in Seismology	5
GEOL 8700	Physical Hydrogeology	25
HONS 2080H	Honors Science	25
FORS 4130	Field Methods	30
FORS 5010/7010	Urban Tree Management	30
CRSS 4540/6540	Pedology	25
CRSS 4600/6600	Soil Physics	30

Section II. Budget

A. Proposed Budget

Year 1:

Item	**Quantity**	**Total Cost**	**Requested from LTG**	**Provided by Other Sources**
MASW 4.5-Hz, single-component geophones	75	$11,112.35	$11,112.35	0

Year 1 (cont'd.):

Item	**Quantity**	**Total Cost**	**Requested from LTG**	**Provided by Other Sources**
Kansas Geological Survey *"SurfSeis"* Software package for analysis of seismic surface waves; permanent licenses	2 (first license: $2575; subsequent licenses: $1700)	$4,275	0	$4,275
Kansas Geological Survey *"SurfSeis"* software package; 6-month "classroom" licenses	5	$1,375	$1,375	0
TOTALS		**$16,762.35**	**$12,487.35**	**$4275**

Year 2:

Item	**Quantity**	**Total Cost**	**Requested from LTG**	**Provided by Other Sources**
Kansas Geological Survey *"SurfSeis"* Software package for Analysis of seismic surface waves; permanent license	3	$5,100	$5,100	0
Intelligent Resources, Inc. *"Rayfract Version 2.51"* software package for tomographic analysis of seismic waves	4	$7,040	$7,040	0
Golden Software *"Surfer 8"* software package, used in conjunction with *"Rayfract"* for generating final plots	2	$960	$960	0
TOTALS		**$13,100**	**$13,100**	**0**

B. Project Timeline

Date	**Objective**	**Person Responsible**
12/1/08 – 8/15/09	Purchase and installation of all software	Robert Hawman
6/1/09 – 7/31/09	Development of field and laboratory exercises for GEOL 4620/6620, 3020, 4220/6220	Robert Hawman
9/1/09 – 12/1/09	Field experiments and data analysis for GEOL 4620/4620. Shorter demonstration projects for GEOL 3020 and 4220/6220.	Robert Hawman
1/10 – 5/10	Single-day demonstrations for courses in other programs (Anthropology/Geology, Forestry, Crop & Soil Sciences)	Robert Hawman
7/1/10 – 7/31/10	Installation of software	Robert Hawman
6/1/10 – 7/31/10	Development of exercises for analysis of synthetic data for simulation of global earthquake studies, for GEOL 4600/6600 and GEOL 8030	Robert Hawman
9/10 – 5/11	Single-day demonstrations for courses in other programs (see above)	Robert Hawman
9/10 – 5/11	Single-day demonstrations for GEOL 1250, HONS 2080H, and the optional field-trip program for GEOL 1121	Robert Hawman

C. Budget Narrative

All of the hardware (geophones) will be purchased during the first year. Franklin College is providing support for the purchase of two permanent licenses for the *"SurfSeis"* package. Other software purchases for the first year include five "classroom" six-month licenses for "*SurfSeis"* (available only with purchase of a permanent license). Software purchases for the second year include three additional permanent academic licenses for *"Surfseis"*, four permanent licenses for *"Rayfract"*, and two permanent licenses for"*Surfer 8"* (the *"Surfer 8"* package is used in conjunction with the *"Rayfract"* package to generate final plots) to allow for continued access for multiple users across campus. Existing computer facilities will be used to run the software.

Section III. Learning Outcomes

During Year 1 (Fall 09-Spring 10), projects will focus on the analysis of surface waves:

1. Students will carry out extensive (multi-week) projects incorporating field experiments and data analysis for GEOL 4620/6620 *(Fall 09). Students will be expected to learn the fundamentals of experiment design and data processing. Learning evaluation will be based on student written reports and exam questions; project evaluation will be based on the quality of the field experiment results and student comments regarding the quality of the field and lab technology experience on course evaluations.*
2. The Project Director will supervise 2-day to 3-day demonstration projects for GEOL 3020, 4220/6220, and 4700 *(Fall 09). Learning evaluation based on questions on exams; project evaluation based on course evaluations (see 1.)*
3. The Project Director will also present more focused, single-class and/or single-day demonstrations for courses in other programs (Anthopology, Forestry, and Crop & Soil Sciences) *(Spring 10). Learning evaluation based on answers to questions handed in the class day following the day of the demonstration.*

During Year 2 (Fall 10-Spring 11), projects will be added for tomographic inversion of P waves:

1. Both the surface-wave and tomography software will be used for projects involving the analysis of synthetic data for GEOL 4600/6600 and GEOL 8030. *Students will be expected to learn the mathematical theory behind the inversion techniques and gain experience modeling structures in the Earth's mantle and crust. Learning evaluation based on student written reports and exam questions; project evaluation based on course evaluations.*
2. The shorter-duration demonstrations and projects begun in Year 1 (items 2-3) will be continued.
3. Single-day demonstrations suitable for introductory classes will be added to the laboratory sections for GEOL 1250, HONS 2080H, and the optional field-trip program for students in Geology 1121. *Learning evaluation based on written laboratory exercise; project evaluation based on student evaluations for course.*

Overall, project evaluation will also be based on the number, quality, and scope of independent student projects initiated using the field equipment and/or software.

Section IV. Support Plan

Software will be installed and maintained by the Project Director, with help from Michael Lewis, Information Technology Professional for the Geology Department. The hardware will be maintained by the Project Director, with assistance from technical staff at Incorporated Research Institutions for Seismology (IRIS), a consortium of university seismology programs joined by the UGA geology department in 1990. The Project Director has over 25 years experience in the maintenance of geophysical field equipment, software development in Fortran and C, and installation and maintenance of third-party software.